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BREAKING COAL WITH AIRDOX

BY

J. S. MALESKY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

BREAKING COAL WITH AIRDOX[1]

By J. S. Malesky[2]

CONTENTS

	Page
Introduction	1
Acknowledgment	2
History	2
Description of Airdox equipment and installation	3
Use of Airdox	6
Production and accidents	8
Hazards in the use of Airdox	8
Conclusions	9

ILLUSTRATIONS

Fig.		Following page
1.	Surface Airdox room and compressors (front view)	4
2.	Assembly Airdox tube	4
3.	Cross section - valve open (Airdox tube)	4
4.	Cross section - valve closed (Airdox tube)	4
5.	Details of blow-down valve	4
6.	Airdox tube testing chamber	8
7.	Inserting Airdox tube into a borehole (Mine A)	8
8.	A place ready for breaking coal (Mine A)	8
9.	Operating blow-down valve (see pressure-indicating gage)	8
10.	Coal broken in a working place (Mine A)	8
11.	Preparation of a working place (Mine B)	8
12.	Coal breaking in progress (Mine B)	8
13.	Coal breaking completed (Mine B)	8

INTRODUCTION

The Airdox method of breaking coal utilizes compressed air under high pressure and was developed to replace explosives. It is used in Illinois and Indiana mines to a large extent and also has been introduced in mines in a few other States.

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ACKNOWLEDGMENT

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HISTORY

In the early 1920's, with the adoption of mechanical mining in States where on-shift shooting was prohibited, it became desirable to develop some means of breaking coal from the face without the use of explosives. At that time it was thought that a pressure of 20,000 pounds per square inch would be necessary to break the coal. It was impossible to obtain a compressor that would develop this pressure; therefore, the patentees developed and applied the Cardox method, which utilizes liquid carbon dioxide as the blasting medium.

The Cardox blasting device consists of a hollow cylindrical steel shell with its length and diameter proportioned to allow the device to be placed in boreholes drilled into the coal to be blasted. The Cardox shell is filled with liquid carbon dioxide, in which is immersed a combustible, oxygenated heater element. The heat energy generated when the heater element is fired electrically gasifies the liquid and builds up high pressure within the shell. A replaceable steel disk is ruptured under increasing gas pressure, and the carbon dioxide gas is discharged at high velocity into the borehole with enough pressure to break the coal.

When experience with the Cardox method indicated that pressures lower than 20,000 pounds per square inch would dislodge coal from a solid face that had been undercut, the original patentees of Cardox returned to the use of compressed air as a disruptive agent. The early experiments were conducted in southern Illinois by using a 4-stage, motor-driven compressor capable of developing a pressure of 15,000 pounds per square inch. The compressed-air device known as the Energy Air Miner made use of a steel shell similar to a Cardox shell, except that the disk was ruptured by compressed air instead of carbon dioxide, and no heater element was used.

Coincident with the work on the Energy Air Miner, the Safety Mining Co., now known as the Cardox Corp., began similar work with an entirely different type of shell. A shell was developed with a piston valve to permit release of the air at the back of the borehole at any desired pressure, depending on the estimated amount of coal to be broken. This is the method now marketed under the trade name of Airdox.

Airdox utilizes a valve release whereby air under high pressure is discharged into a borehole by opening a valve in the copper line that conducts the compressed air to the working face and closing the valve after a predetermined pressure has been obtained in the Airdox tube (commonly called a shell, but designated by the manufacturer as the Airdox tube). The valve release should be installed in the copper tubing at a safe distance from the Airdox tube that has been inserted in the drill hole.

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An Airdox tube consists of a hollow steel chamber of suitable length and diameter to permit placement of the device in a borehole drilled in the coal to be broken. The Airdox tube is capped at the outby end and contains a tube top nose to protect the copper tubing where it enters the Airdox tube, a piston, a piston rod, a spherical slide valve, and a valve seat. When air pressure is applied, the forward movement of the piston, piston rod, and slide valve causes the compressed air to be trapped in the Airdox tube. On releasing the air at the charging end, the piston moves the spherical sliding valve away from the valve seat, which causes a sudden discharge of air at the back of the borehole owing to the large drop in pressure.

Air at pressures of 10,000 pounds per square inch or more is conducted from compressors by means of steel air lines and copper tubing to places of application.

Among the safety features with the use of Airdox are: No spark or flame is necessary to discharge the Airdox tube; the dangers of handling and storing explosives on the surface, underground, and in the face regions are eliminated; also, the Airdox tube is inactive until charged with compressed air. A disadvantage is the hazard resulting from the rupture of a compressed-air line, which will thrash about and may injure persons or raise mine dust into suspension until the compressed air can be shut off.

The terms "shooting" and "blasting" are not applicable to Airdox; a more accurate description is "breaking." Shooting or blasting, as used in the case of explosives, due to the instantaneous release of the gaseous products at high pressures tends to shatter, tear, and rend the coal, whereas the action of Airdox is more a displacement of the coal by a comparatively slower discharge of the compressed air. The air under high pressure tends to force the coal from the face by constant pressure rather than by sudden shock, which results in a pronounced shattering effect.

Both for safety and efficiency in breaking coal, at least two free faces must be provided. This is accomplished by undercutting, centercutting, or shearing. The free faces give room for displacement of the coal, an important factor in producing better commercial sizes of the final product. Undercutting is the common practice where Airdox is now being used.

DESCRIPTION OF AIRDOX EQUIPMENT AND INSTALLATION

The most recent installations of Airdox consist of 5- and 6-stage compressors capable of developing a pressure of 10,000 or more pounds per square inch; moisture and oil traps; steel air lines with an outside diameter of 1 inch and inside diameter of 5/8 inch, previously tested to a pressure of 20,000 pounds per square inch, to conduct the air into the mine and to the working sections; flexible copper tubing with 3/8-inch outside diameter and 7/40-inch inside diameter to conduct the air from the steel air lines to the working faces; special steel Airdox tubes for confining the compressed air in boreholes; a series of valves for controlling the flow of air; and pressure gages to indicate the air pressure delivered to the working areas.

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In most of the recent Airdox installations, the compressors are on the surface (fig. 1). They have either 5 or 6 stages and are driven by 50-horsepower direct- or alternating-current motors by which the air is compressed to 10,000 or more pounds per square inch. The few 5-stage compressors now in use are being replaced with 6-stage compressors.

When a 5-stage compressor is used, the steps are approximately as follows:

First stage to	40	pounds per square inch
Second stage to	200	pounds per square inch
Third stage to	800	pounds per square inch
Fourth stage to	2,700	pounds per square inch
Fifth stage to	10,000	pounds per square inch

When a 6-stage compressor is used, the steps are approximately as follows:

First stage to	35	pounds per square inch
Second stage to	130	pounds per square inch
Third stage to	410	pounds per square inch
Fourth stage to	1,300	pounds per square inch
Fifth stage to	3,500	pounds per square inch
Sixth stage to	10,000	pounds per square inch

In a few mines, the Airdox compressors are underground. At all installations, the frames of the compressor motors are grounded, and the motors are protected with compensating starters and overload relays. Where they enter the mine, the steel air lines are grounded to a metal rod driven into the earth. The compressors are equipped with automatic pressure unloading devices, which are set to function at predetermined pressures.

When pressure drops in the air lines owing to consumption of air, the automatic starter will operate upon a reduction in pressure of 500 to 700 pounds a square inch. Each compressor is also equipped with a pressure micro-control switch for breaking the circuit on the holding coil of the magnetic contactor that operates the compressor. The micro-control switch releases the contactor that operates the compressor when a pressure of 10,000 pounds a square inch is obtained. Master micro-control switches also are installed in compressor rooms and are kept locked. In the event of tampering with the individual micro-control switches, the master switch is activated and makes all compressors inoperative.

The air at a pressure of 10,000 pounds per square inch is conducted from the compressor to oil and moisture traps (two steel cylinders set on end, fig. 1) through a short piece of 3/8-inch flexible copper tubing. The traps serve principally to catch sediment, oil, and grease and also as storage space for a small amount of air. They should be blown out daily to free them of any foreign matter to prevent the impurities from entering and clogging the air lines. The traps are set upright, and blow-off valves are attached near the bottom, where the sediment collects. The traps should be set inside the compressor rooms; otherwise the sediment has a tendency to thicken during cold weather and will not flow freely when the blow-off valve is opened.

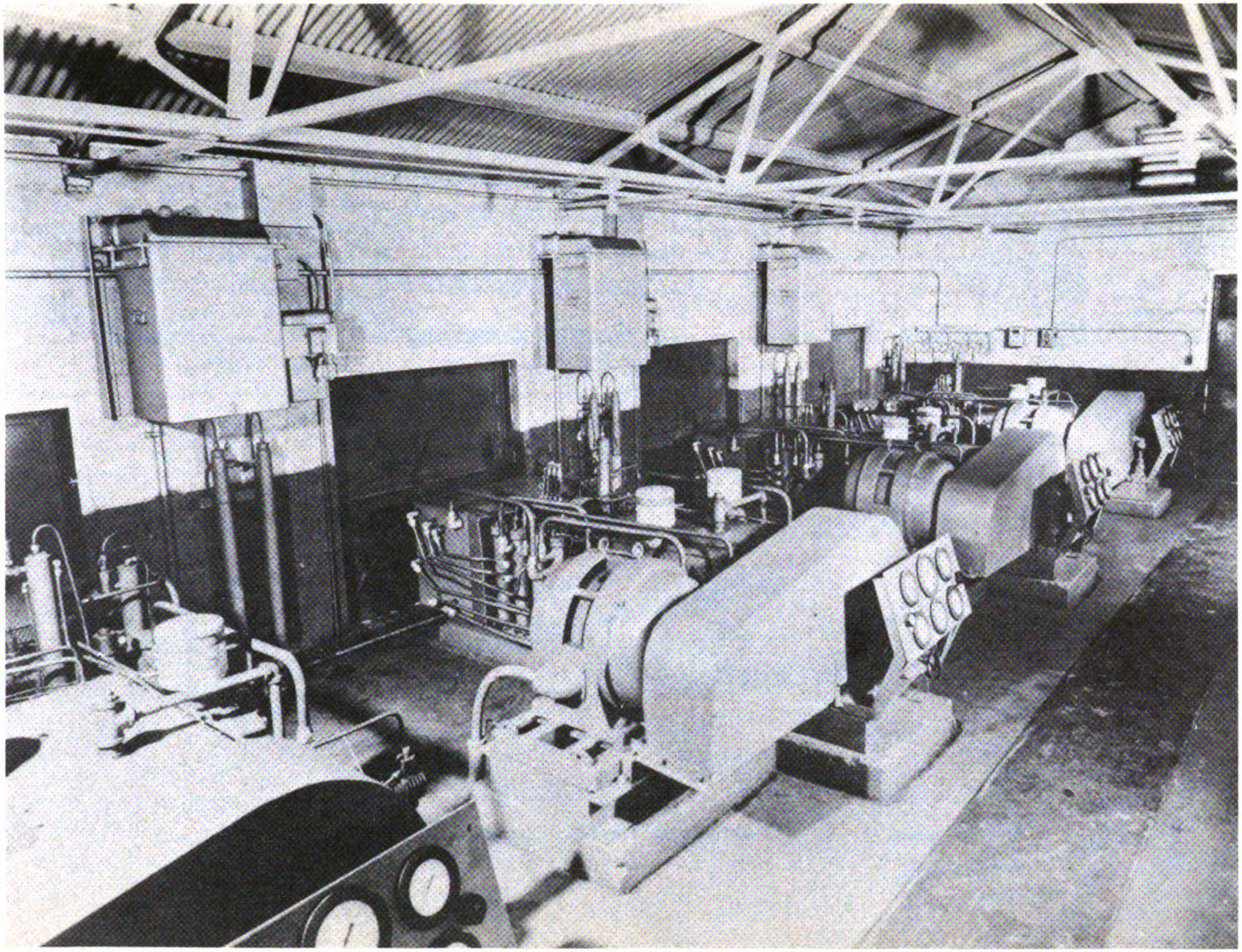
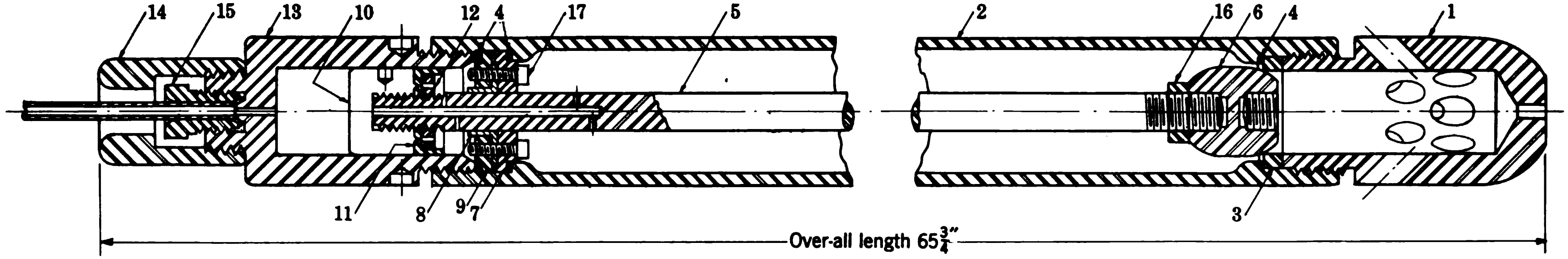


Figure I. - Surface Airdox room and compressors (front view).



1 - 1 Release cap
2 - 1 Tube body
3 - 1 Valve seat
4 - 3 Gaskets - 2" I.D. x 2-23/64 O.D. x 1/16" thick
5 - 1 Piston rod
6 - 1 Valve
7 - 1 Baffle plate
8 - 1 Hat leather
9 - 1 Hat leather keeper

10 - 1 Piston
11 - 1 Cup leather
12 - 1 Cup leather keeper
13 - 1 Tube top
14 - 1 Tube top nose
15 - 1 "B" nut - 1-1/16 hex. hd.
16 - 1 Lock nut - 3/4" - 16 N.F. Th'd.
17 - 4 1/4" 20 N.C. x 1" Lg. hollow hex. hd. cap screws

Figure 2. - Assembly L-230 Airdox tube.

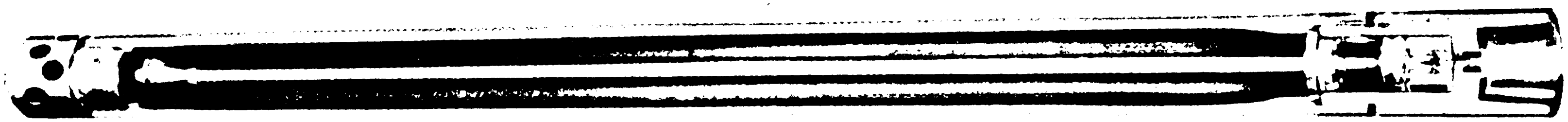


Figure 3. - Cross section of Airdox tube, valve open.

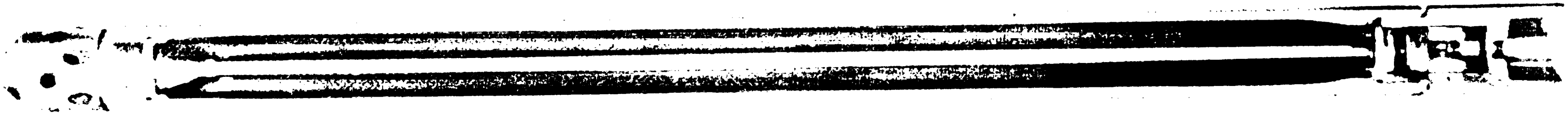


Figure 4. - Cross section of Airdox tube, valve closed.

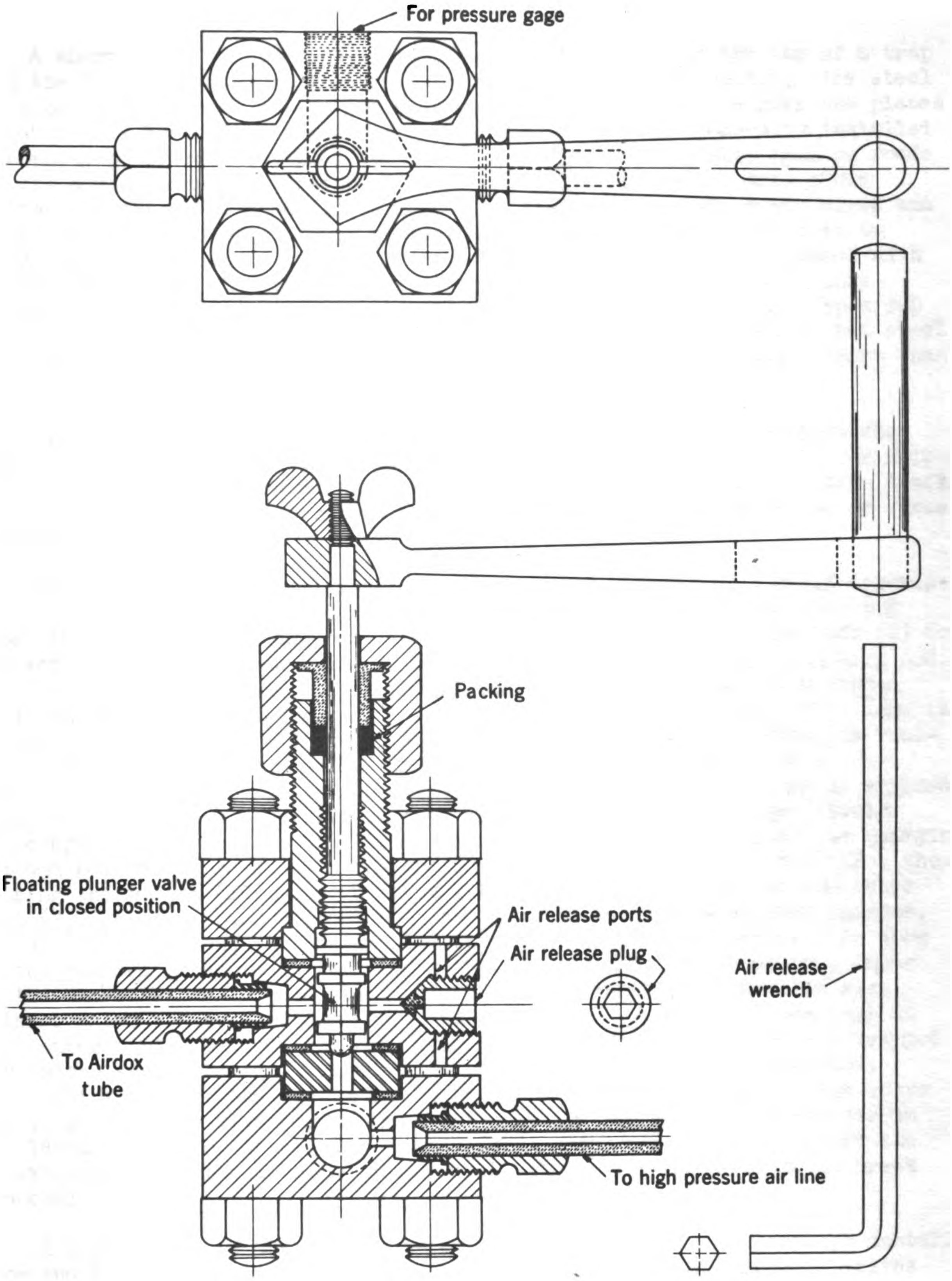


Figure 5. - Details of blow-down valve.

A short piece of 3/8-inch flexible copper tubing joins the top of a trap with the 1-inch steel line through a solid steel-block connection. The steel lines carry compressed air to the working sections of the mine near the places where it will be used to break coal. The steel lines are generally installed in nonhaulage entries parallel to the main- and secondary-entry haulage roads and are buried under the tracks or fastened to the roof where they cross haulage entries. The steel lines should be isolated from all power wires and should be insulated effectively where they cross bare power conductors to insure against active or stray currents. The lines are usually covered with 2-inch plank where they pass under haulage tracks. Compressed air lines should extend as near as practicable to the working faces (not more than 300 feet from a face) to eliminate the need for extensive copper tubing, but steel air lines should not extend into rooms, even though the rooms may be more than 300 feet in length.

From the end of the steel lines, copper tubing is used to conduct the compressed air to the working faces where the coal is to be broken. The copper tubing is installed along a rib of the room to keep it away from haulage tracks and power wires. One copper line is commonly used for a group of two or three working faces.

The assembly of an Airdox tube is shown in figure 2, and a brief description of the various parts and their functions follows: An Airdox tube top nose (14) piece is threaded onto the intake end of the Airdox tube body (2) to protect the copper tubing where it enters the Airdox tube at the charging end. Also, at the charging end and on the inside of the Airdox tube is a piston (10) equipped with a piston rod (5). Into the front end of the Airdox tube is threaded a release cap (1) equipped with a valve seat (3) and portholes similar to those in a Cardox shell. The piston rod (5), equipped with a valve (6) at the discharge end, fits into the valve seat (3) when pressure is applied. Figures 3 and 4 show the valve in open and closed positions, respectively. The compressed air enters the Airdox tube through copper tubing at the charging end and builds up pressure in the small outer chamber of the Airdox tube, thus causing the piston (10) to move forward and seat the valve (6) at the valve seat (3). As the pressure continues to increase in the small outer chamber, the air passes around the piston (10) into the large inner chamber. As soon as the desired pressure in the Airdox tube is reached, the floating plunger at the blow-down valve (fig. 5) is closed by the operator. When the air-release valve at the blow-down valve is opened, it releases the pressure in the copper tubing between the blow-down valve and Airdox tube and the trapped air in the small chamber. This causes the piston (10) to move backward, because the area of the piston is slightly larger than the area of the valve seat, opening the valve (6) at the valve seat (3) and permitting the air in the large chamber of the Airdox tube to escape at high velocity through the release-cap (1) ports into the drill hole with sufficient pressure to break the coal.

A description of the various kinds of equipment used in an Airdox installation and Airdox tube has been given, but this would be incomplete if valves and other connecting material were not described briefly. Suitable unions are

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installed in all steel lines at varying intervals, depending on the method of mining followed; however, an interval of not more than 500 feet has been found to be satisfactory. Valves are generally installed in the steel air lines at 1,000-foot intervals to facilitate bleeding the lines if they should become blocked or if it is necessary to work on the lines. By installing the valves at frequent intervals, the compressed air can be shut off, and a comparatively short length of the line can be bled without draining the entire system of compressed air. Cut-off valves are installed in the branch lines, near the main steel air lines, and also at the inby ends of all steel air lines.

From the ends of the steel lines, flexible copper tubing with reducers, tees, and unions is used to conduct the compressed air to the working faces. Valves are provided at the junction of the steel lines and copper tubing, and intermediate valves are inserted in the copper tubing between the junction valves and blow-down valves. When rooms are comparatively short, the intermediate valves are not necessary. Normally, 50 to 100 feet of flexible copper tubing is attached to an Airdox tube, and such length of tubing is usually ample for safety of the operator when breaking coal, because crosscuts usually are made at frequent intervals where Airdox is used.

USE OF AIRDOX

Although the application of Airdox differs somewhat from the use of explosives and Cardox, the importance of proper face preparation for the efficient and safe use of Airdox cannot be over-emphasized. The use of Airdox does not change the cycle of face operations; the places are cut and drilled in the usual manner. The number of holes and their locations in the face depend upon conditions, type of loading equipment used, and characteristics of the coal bed. The final determination will be the result of trials.

Valuable assistance in developing the proper practices in breaking coal can be rendered by service men skilled in this work. The preparation of the coal face in a workmanlike manner, pulling down loose roof and coal, squaring corners, and eliminating all dangerous overhanging material are as important in breaking coal with Airdox as when blasting with explosives or other blasting devices. The cutting or shearing of coal, or both, and maintaining the place properly with respect to the "sight lines" are equally important in breaking as in blasting coal. Keeping the cut or shear reasonably free of machine cuttings and water tends to increase efficiency and safety in breaking the coal. The drilling of an adequate number of properly placed boreholes is also important. Reasonable precautions should be exercised when breaking coal to see that the holes are not drilled on the solid, in the roof, over heavy rock binders or shale, or in tight corners to avoid the possibility of flying Airdox tubes.

Following the proper face preparation and drilling of boreholes, the Airdox tube and attached piece of flexible copper tubing are brought to the working face that is to be broken. A blow-down valve is attached to the end of the copper line in a crosscut, and 50 to 100 feet of copper tubing is extended from the blow-down valve to the Airdox tube. It is important that the Airdox tube and copper tubing be kept away from the track, drill truck, power cables, or other electric equipment, and any source of stray electric current.

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One of the chief advantages in the use of Airdox is that it does not add any undesirable fume, smoke, or gas to the atmosphere in a working place. The release valve should be installed where the ribs and roof are sound, at least 45 feet from the working face, and around at least one right angle with the center line of the place in which the coal is to be broken. The operator should make certain that all crosscuts and other approaches are guarded before attempting to use Airdox. When the pillar between adjacent places is less than 10 feet in thickness, all men should be removed a safe distance from such places before the compressed air is released. In placing the Airdox tube in a drill hole, it should be pushed to the back of the hole and then withdrawn a few inches to form an air cushion. Washing or cleaning coal dust thoroughly out of the drill holes will reduce the amount of dust thrown into suspension after each discharge of air.

An indispensable accessory in breaking coal with Airdox is the blow-down valve, the details of which are shown in figure 5. Immediately before turning on the air at the blow-down valve, the air-release plug is tightened in the closed position; the user gives vocal warning and then opens the floating plunger valve slowly to permit the piston rod in the Airdox tube to seat properly before the floating plunger valve is opened wide. The floating plunger valve is left open long enough for the Airdox tube to develop the desired pressure, which is registered on the pressure gage attached to the blow-down valve. This may require about 20 seconds. A second warning is given, the floating plunger valve is closed, and the air-release plug is loosened with the air-release wrench to permit the air in the copper tubing between the blow-down valve and the charging end of the Airdox tube to escape at the air-release ports. This releases the trapped air suddenly from the Airdox tube at the capped discharge end and breaks the coal so that it can be loaded readily without undue shattering. The floating plunger valve is left in a closed position and the air-release plug remains loose until the Airdox tube is placed in the next borehole. This procedure is repeated until all of the coal in a working place has been broken. After dislodging the coal, the copper tubing is disconnected either at the blow-down valve or at the Airdox tube, then both it and the Airdox tube are dragged to the next place of use. Dragging eliminates the need of excessive coiling and uncoiling the copper tubing. It is important that the copper tubing be examined frequently for kinks and weaknesses; replacements should be made when defects are found. The part of the copper tubing that is attached to the Airdox tube is affected most by frequent coiling and uncoiling and requires periodic replacement because of the dangers from kinking and resultant failure of metal. The Airdox tube should be disconnected from the copper tubing when not in use, and the tubing should be coiled and placed in a safe place.

From 40 to 80 seconds are required for each discharge of air. After each discharge, a fog is evolved, owing to the sudden release of the air at a working face. This fog soon disappears. In breaking coal with Airdox, if there is a tendency for a discharge to delay slightly more than the usual length of time necessary, the Airdox tube should be taken out of service and repaired to eliminate delayed or missed discharges. Delayed and missed discharges can be greatly reduced by maintaining the Airdox tubes properly, keeping valves and valve seats in good condition, using copper tubing of ample strength, using efficient release valves, and having well-prepared connections at the lines and Airdox tubes.

Often Airdox-tube testing chambers (fig. 6) are constructed so that the Airdox tubes can be tested before using to break coal. The chambers are made of concrete and are valuable in maintaining the Airdox tubes in good condition.

The mines in Indiana and Illinois in which coal is broken with Airdox utilize a room-and-pillar system and have many similar natural conditions and operating methods. The coal is loaded entirely by loading machines.

Disregarding the initial investment and operating cost of Airdox, it might be well to compare it with ordinary explosives. Drilling when using Airdox is more difficult, because more and larger holes are required than for explosives. The use of Airdox increases the amount of equipment for maintenance and repair. The general belief of those using Airdox is that the broken coal is much firmer, with much less degradation from handling, than the same coal shot with explosives. An advantage in favor of breaking coal with compressed air is that the standing face and ribs are less disturbed than when explosives are used, so that the hazard from falling face or rib coal should be reduced. In States where the use of explosives during the working shift is prohibited by law, the use of the Airdox method of breaking coal permits more rapid advancement, particularly with development, because more than one "cut" of coal a shift can be loaded in each working place.

Figures 7 and 8 and 10 to 13 show various steps in the use of Airdox in two mines. Figure 9 shows the blow-down valve and pressure-indicating gage.

PRODUCTION AND ACCIDENTS

From 1938, when Airdox was first used, to the end of 1947, 41,704,000 tons of coal was broken by means of it. During this period, one fatal accident was attributed directly to its use. This record is somewhat better than that with explosives and other blasting devices. Lost-time injuries from using Airdox are caused principally by ruptured air lines and coal flying from a discharge of air.

HAZARDS IN THE USE OF AIRDOX

The chief hazard introduced by the use of Airdox is the possibility of injury to persons from ruptured steel or copper air lines or that a ruptured air line may thrash about and raise mine dust into suspension until the compressed air can be shut off.

The frequent coiling and uncoiling of the copper tubing weakens it, and straightening the kinks is hazardous, particularly if high-pressure air is in the tubing. To overcome the danger from failure of the copper tubing, it should be replaced at the first sign of weakness. Under no circumstance should work be done on the copper tubing until the line is "bled" of compressed air.

A possible cause of rupturing air lines is "pitting" due to power leaks, especially where the air lines cross bare power wires and effective insulation is not provided. An arc or short circuit to an air line may cause a

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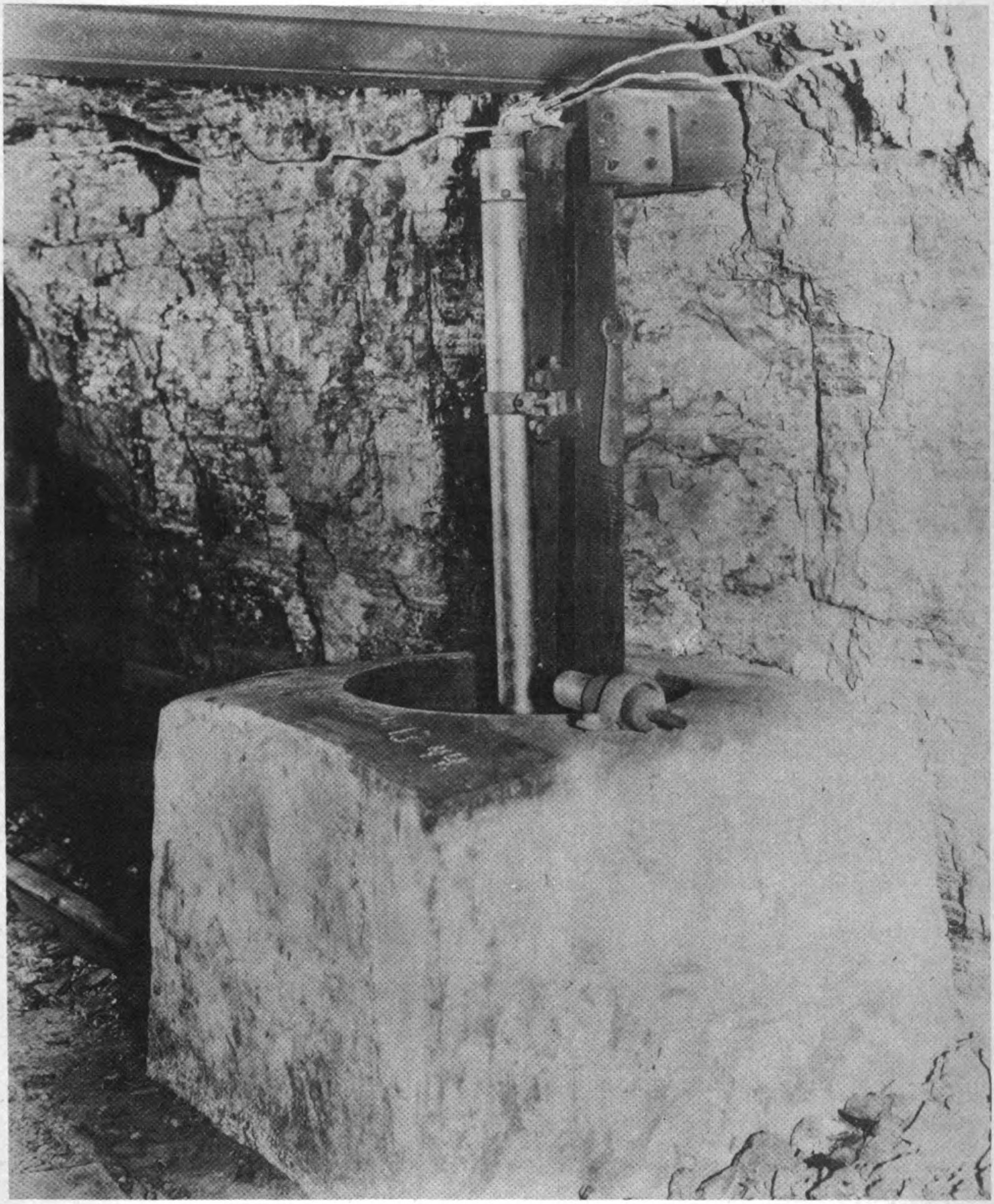

Figure 6. - Airdox-tube testing chamber.

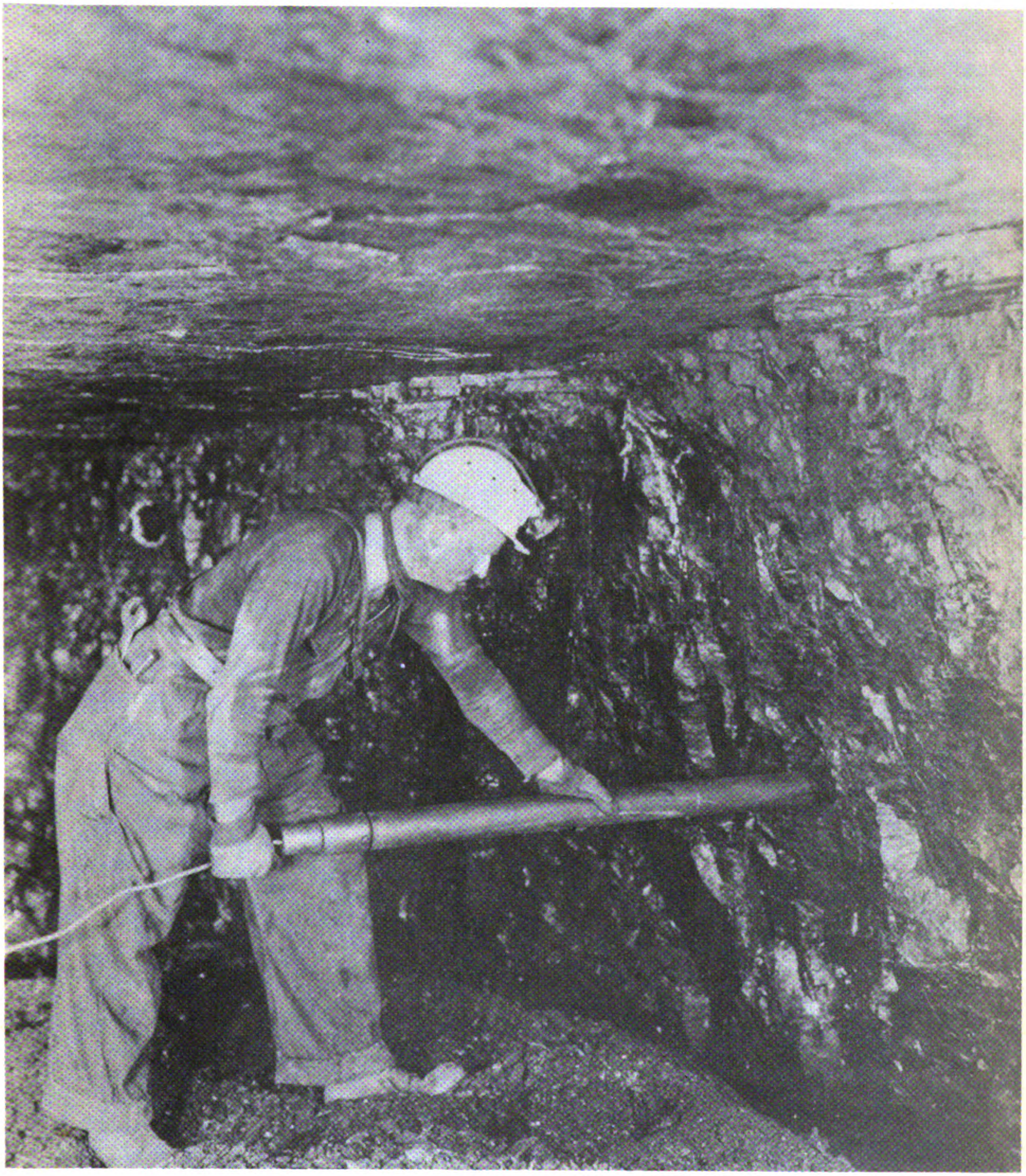

Figure 7. - Inserting Airdox tube into a borehole, Mine A.

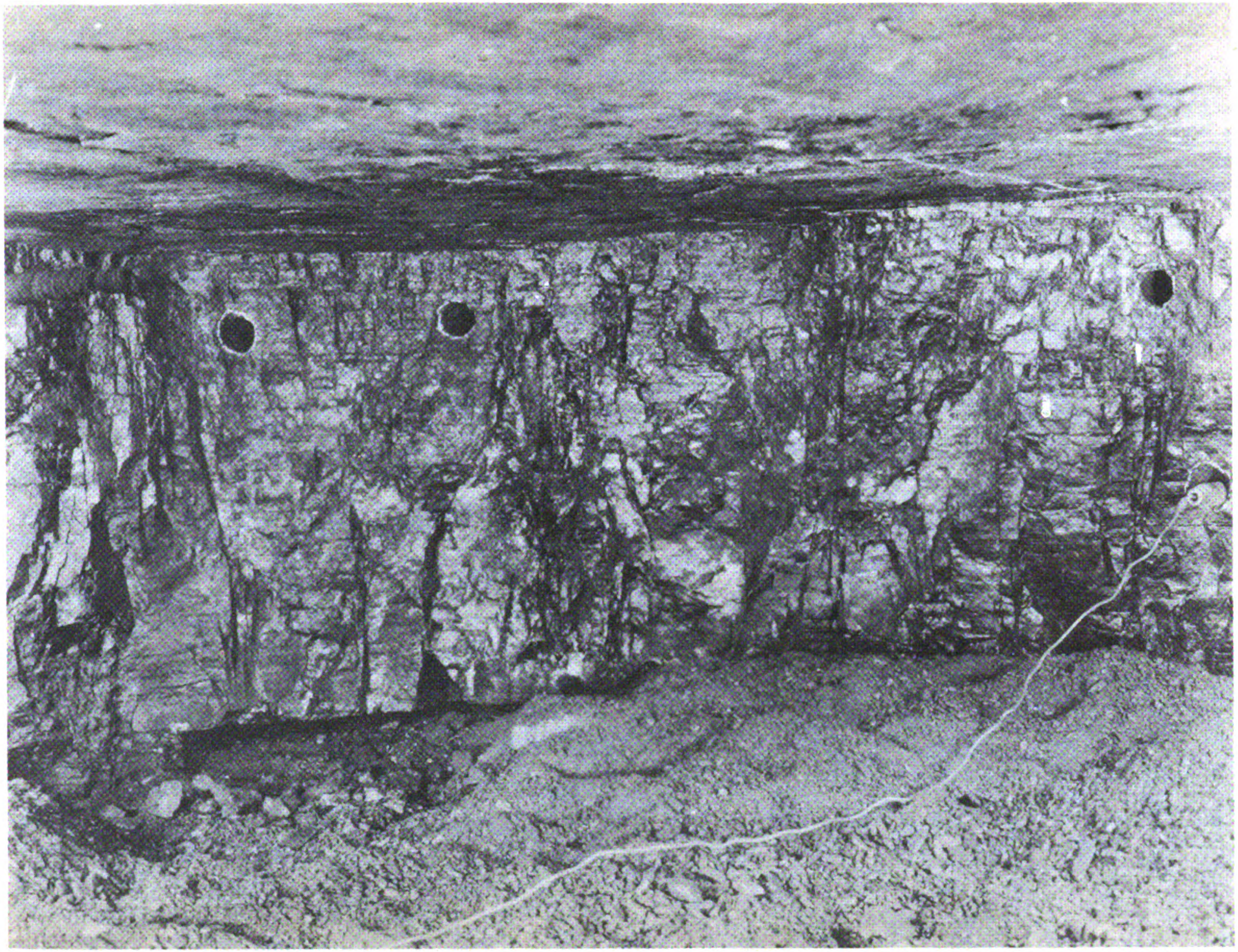

Figure 8. - A place ready for breaking coal, Mine A.

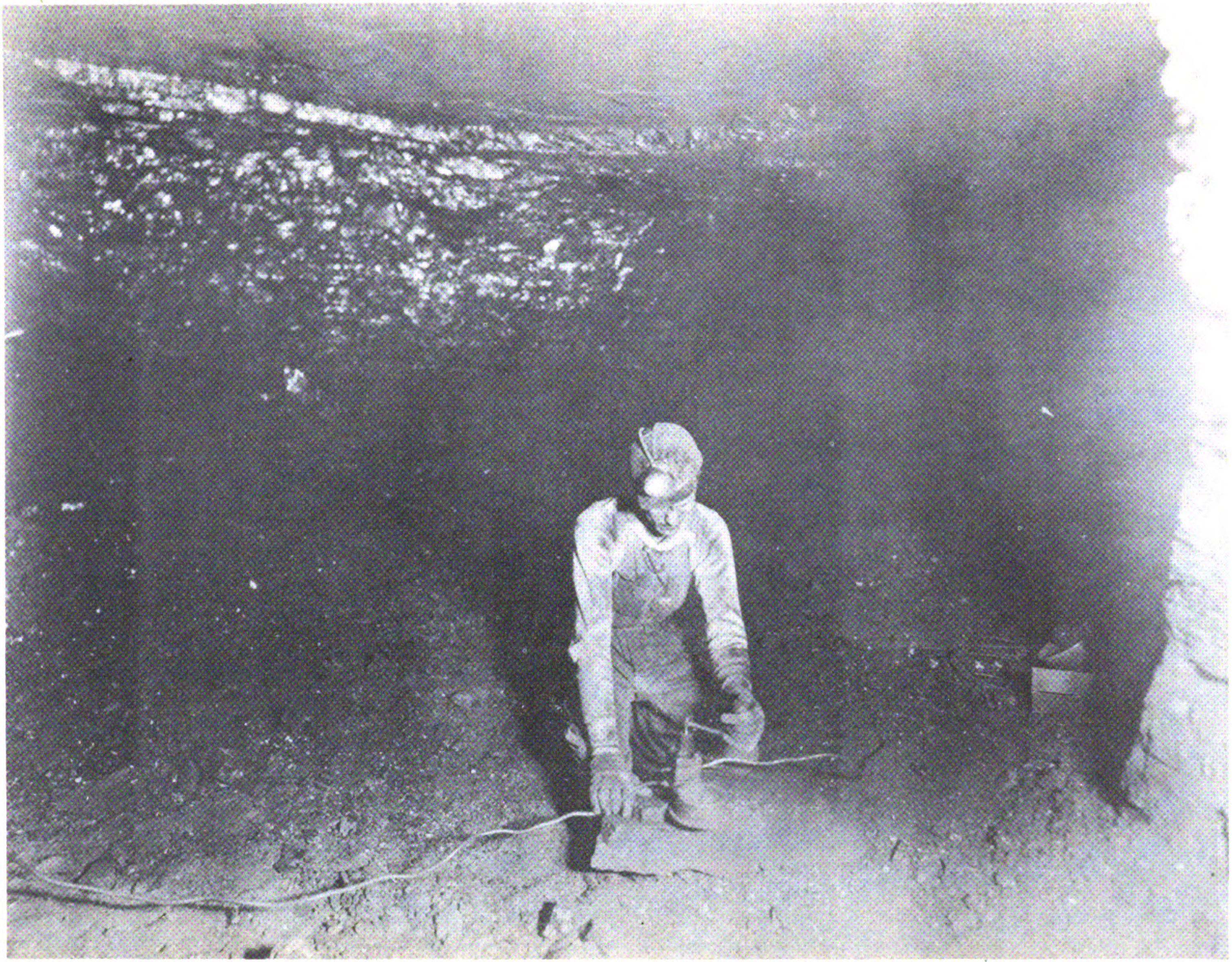

Figure 9. - Operating blow-down valve (see pressure-indicating gage).

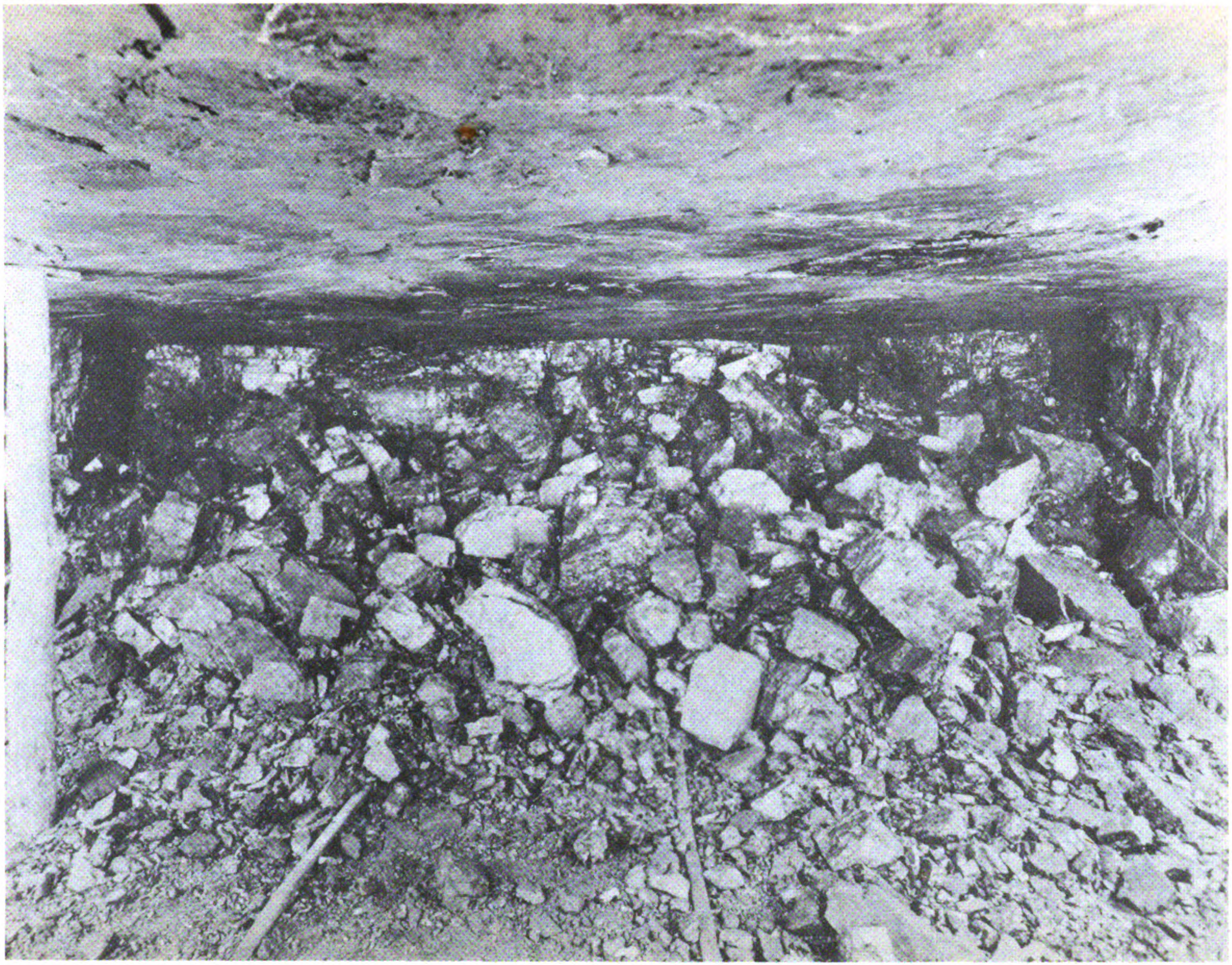

Figure 10. - Coal broken in a working place, Mine A.

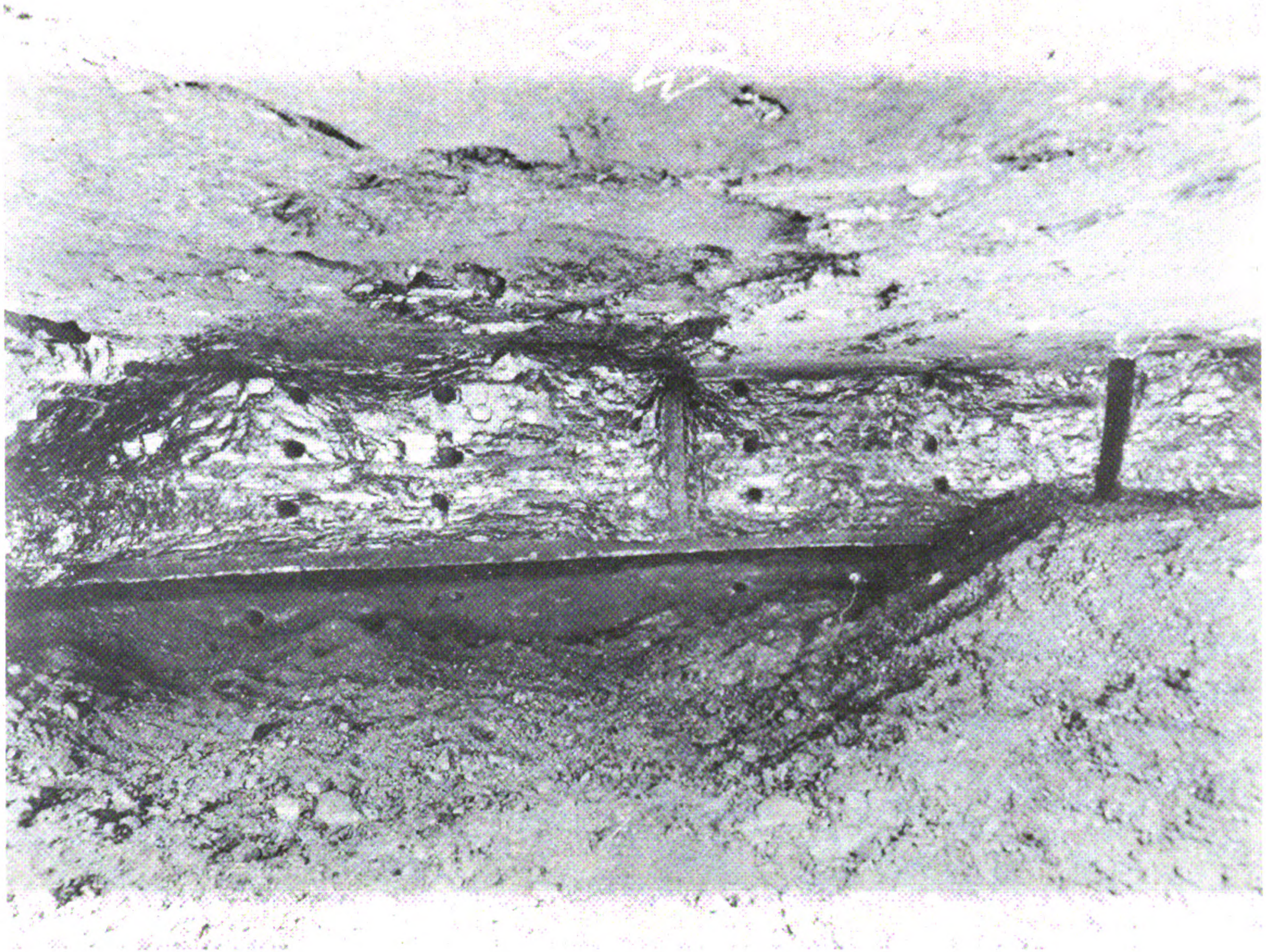

Figure 11. - Preparation of a working place, Mine B.

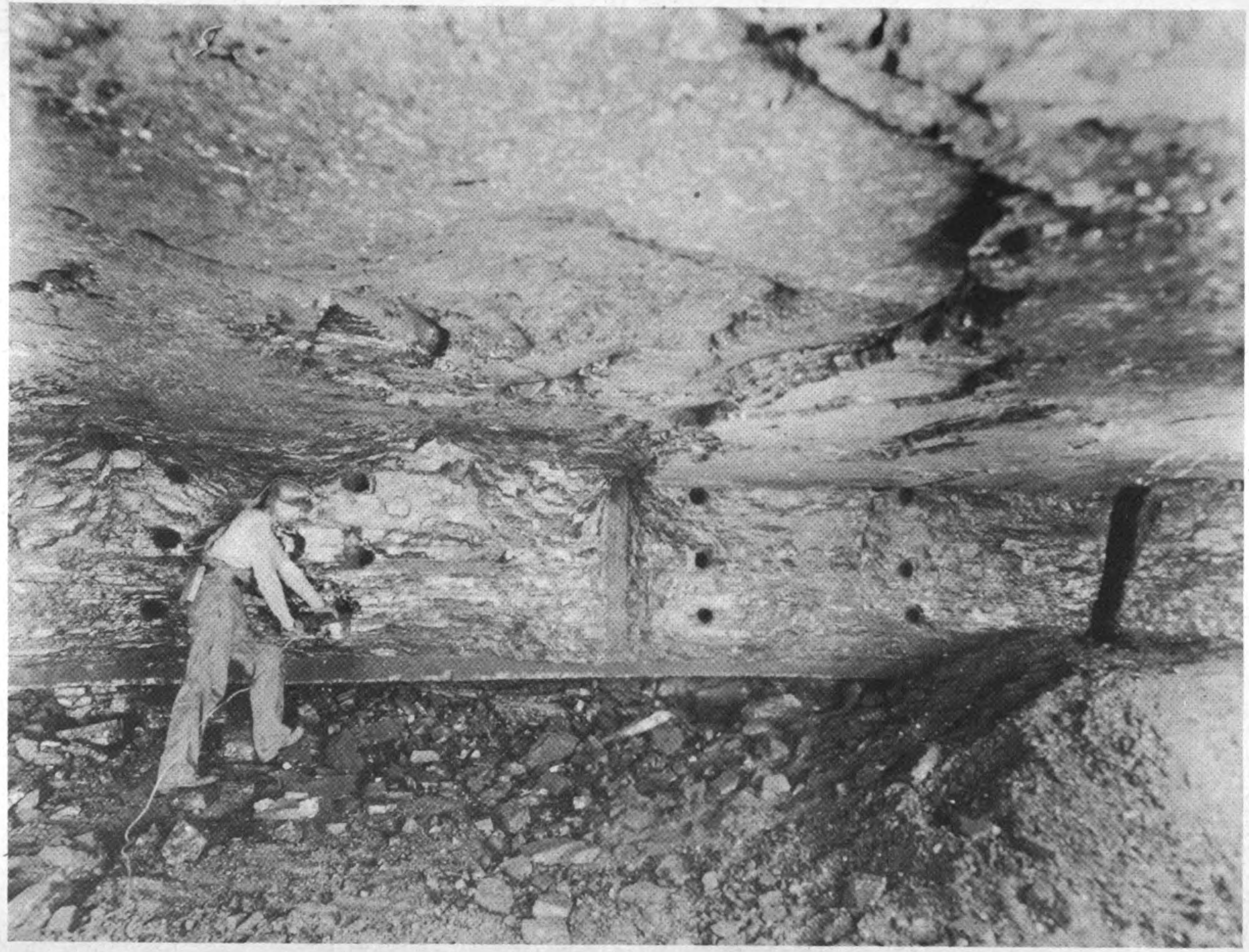

Figure 12. - Coal breaking in progress, Mine B.

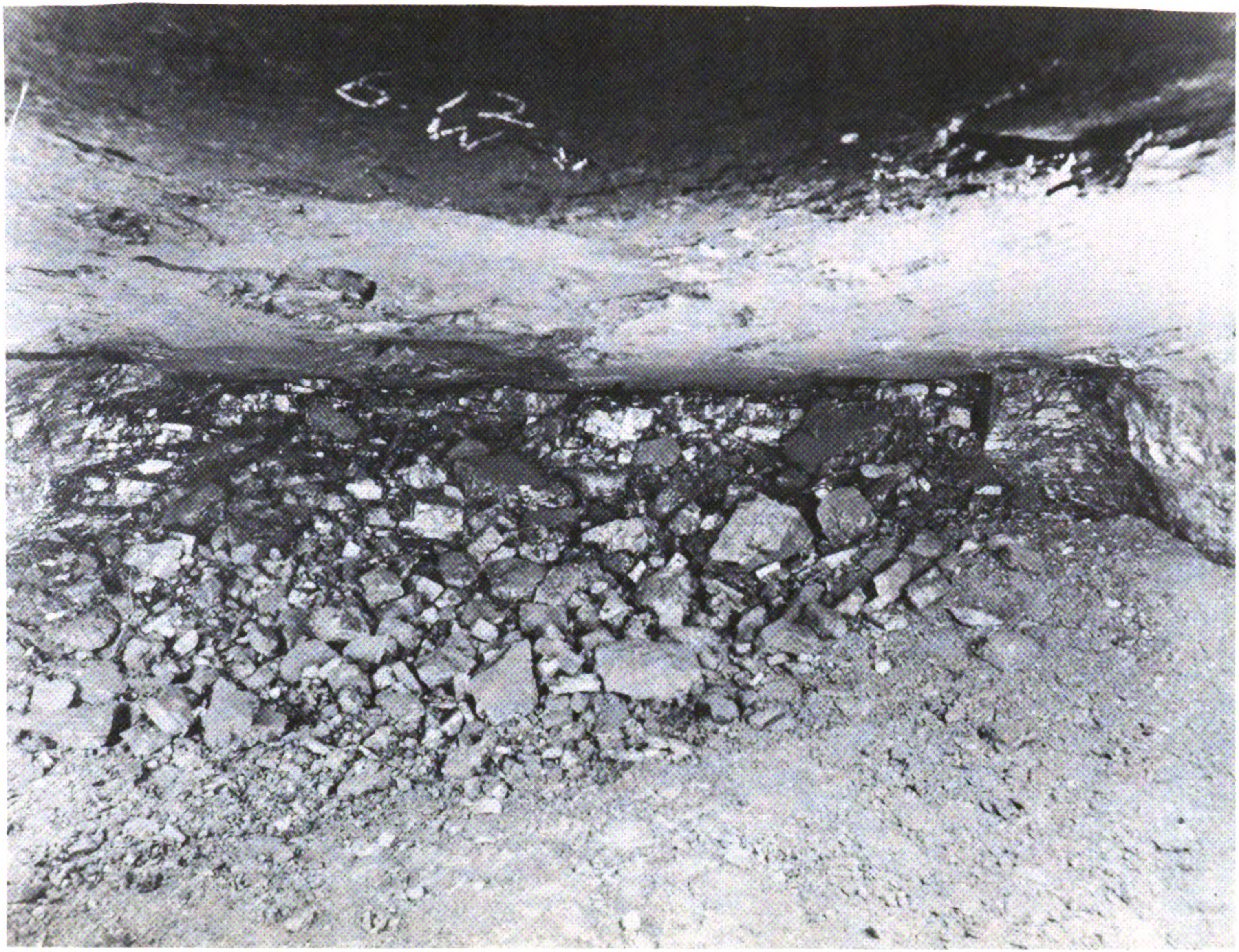

Figure 13. - Coal breaking completed, Mine B.

hole to be burned in it, resulting in a rupture. The installation of air lines along haulage entries presents a hazard because a wrecked or derailed trip may break a line and cause it to thrash about with consequent raising of mine dust into suspension. However, an advantage in the use of the steel and copper lines is that they do not fly into pieces but split longitudinally when ruptured.

CONCLUSIONS

Some of the safety advantages in the use of Airdox are:

1. No spark or flame is necessary to discharge the Airdox tube.

2. The attendant hazards when explosives are stored and handled on the surface, underground, and in the face regions are eliminated.

3. The Airdox tube is inactive until compressed air is admitted to it.

4. The comparatively slow action of compressed air disturbs the roof and ribs less than when explosives are used.

5. Airdox tubes rarely leave the boreholes upon discharging, but if one does, the copper tubing has a tendency to retain them within a few feet of the face.

6. Objectionable fumes, smoke, and gases are not present at the face of the working place after each discharge. One can safely return to the face immediately.

7. Good visibility is maintained because only a small amount of dust is thrown into suspension.

8. As compressed air is available at all working faces, men behind a barricade may be able to obtain a supply of fresh air from the lines in the event of disaster. In September 1944, a local gas ignition occurred in a mine where Airdox was used, and an employee claims to have saved his life by crawling to a blow-down valve, opening it, and breathing the escaping compressed air. The employee, a loading-machine operator, was about 120 feet from the origin of the explosion and was knocked down by it. On reaching a nearby blow-down valve, he partly opened it and covered his head with a piece of brattice cloth, putting his face near the escaping compressed air.

A few additional advantages, other than safety, gained from the use of Airdox are:

1. Substantial decrease in the amount of minus 2-inch coal, particularly the minus 1/4-inch size.

2. Production of coal with a firmer structure.

3. "On-shift" breaking of coal, in States where blasting with explosives is prohibited during the working shift, expedites development.